

Monitoring and language switching

A domain-general monitoring account of language switching in recognition tasks: Evidence for adaptive control*

Esli Struys^{1,2,3,4}, Evy Woumans⁵, Soudabeh Nour^{2,3}, Olga Kepinska^{4,6},
& Maurits Van den Noort^{2,7}

¹Centre for Linguistics, Vrije Universiteit Brussel, Belgium.

²Brussels Institute for Applied Linguistics, Vrije Universiteit, Belgium.

³Centre for Neurosciences, Vrije Universiteit Brussel, Belgium.

⁴Leiden University Centre for Linguistics, Leiden University, The Netherlands.

⁵Department of Experimental Psychology, Ghent University, Belgium.

⁶Leiden Institute for Brain and Cognition, Leiden University, The Netherlands.

⁷Research Group of Pain and Neuroscience, Kyung Hee University, Republic of Korea.

***Acknowledgements**

We are grateful to the Research Council of the Vrije Universiteit Brussel for their generous support in funding the present research.

Address for correspondence:

Esli Struys
Vrije Universiteit Brussel
Pleinlaan 2
1050 Elsene
Belgium
estruys@vub.ac.be

1 **Abstract**

2 Language switching experience is assumed to have an effect on domain-general
3 control abilities in bilinguals, but previous studies on the relationship between these
4 two variables have generated mixed results. The present study investigated the effects
5 of bilingual experiences on the interaction between language switching and domain-
6 general control. Thirty-two Dutch-French bilingual young adults executed a bilingual
7 categorisation task to assess their language switching abilities and a Simon task to
8 assess domain-general control. The results show that global response times on the
9 Simon task were correlated to the forward switch cost (from L1 to L2); moreover,
10 interestingly, the forward switch cost was found to be related to recent language
11 exposure but not to the age of second language acquisition. We suggest a monitoring
12 account of language switching to integrate the first finding with previous studies and
13 we interpret the second finding as support for the adaptive control hypothesis.

14 **List of keywords**

15 Language switching, Simon task, bilingualism, cognitive control, bilingual advantage,
16 executive functions

17

18

19

20

21

22

23

24

25

1 **Introduction**

2 How do bilinguals manage two language systems in their daily interactions?

3 This question has led to a considerable number of studies over the last decade (Kroll
4 & Bialystok, 2013). In general, these studies show involvement of cognitive control
5 during bilingual language management (Bobb, Wodniecka, & Kroll, 2013). As a
6 result, the use of multiple language systems on a daily basis may result in training
7 effects such as improved performance on non-verbal executive functioning tasks (for
8 a recent review, see Zhou & Krott, 2016). However, these training effects are
9 controversial because it is unclear exactly how cognitive control is related to language
10 management in the bilingual mind (e.g. Paap & Greenberg, 2013). Moreover, it is still
11 unknown which components of the bilingual experience contribute to these training
12 effects (e.g. Hartanto & Yang, 2016). Therefore, in order to make progress, a better
13 understanding of the interaction between the mental control of language systems in
14 the bilingual mind and domain-general cognitive control is needed.

15

16 ***Domain-general control and language control***

17 Domain-general or cognitive control refers to all mental processes that
18 regulate other cognitive activities (Miller & Cohen, 2001). According to the ‘unity
19 and diversity’ model of cognitive control, these processes can be classified into three
20 separable domains: inhibition of prepotent responses, shifting between mental sets,
21 and updating and monitoring of working memory representations (Miyake et al.,
22 2000). These processes are particularly relevant for bilingualism because many
23 studies have suggested a bilingual advantage in cognitive control based on their
24 superior performance compared to monolinguals on interference tasks with conflict
25 trials such as the Simon task (for a recent review, see Zhou & Krott, 2016). The main

1 idea behind this bilingual advantage is that there is an overlap between the domains of
 2 language and cognitive control and that their constant exposure to two (or more)
 3 languages gives bilinguals a training advantage over monolinguals (Garbin et al.,
 4 2010; Weissberger, Wierenga, Bondi, & Gollan, 2012). The bilingual advantage is
 5 assumed to stem from the daily usage of both languages, both in the monolingual
 6 mode, when bilinguals have to suppress interference from the non-target language
 7 while speaking or recognising the target language (e.g. Lemhofer, Dijkstra, & Michel,
 8 2004; Starreveld, De Groot, Rossmark, & Van Hell, 2014), and in the bilingual mode,
 9 when bilinguals need to be able to produce or recognise language switches (e.g.
 10 Abutalebi & Green, 2008; Thomas & Allport, 2000).

11 However, taking into account the diversity of cognitive control processes, it is
 12 unclear exactly which of these three processes (inhibition, shifting, or updating) is
 13 being trained by active bilingualism. While some studies have suggested a specific
 14 advantage on inhibitory control as indexed by a smaller conflict effect in interference
 15 tasks (e.g. Bialystok, Craik, & Luk, 2008; Poarch & van Hell, 2012; Tse & Altarriba,
 16 2014), others have proposed a more general cognitive advantage indicated by overall
 17 better performance (e.g. Coderre & van Heuven, 2014; Costa, Hernandez, Costa-
 18 Faidella, & Sebastian-Galles, 2009; Struys, Mohades, Bosch, & van den Noort, 2015).
 19 In a review study on the empirical evidence for the bilingual advantage, Hilchey and
 20 Klein (2011) report that this specific inhibitory control advantage on conflict trials is
 21 not as prevalent in the literature as the finding of better global performance for
 22 bilinguals on both conflict and non-conflict trials. The latter has been interpreted as a
 23 conflict monitoring advantage (Costa et al., 2009). In light of the ongoing controversy
 24 on the existence of a bilingual advantage (Paap, Johnson, & Sawi, 2015; von Bastian,

1 Souza, & Gade, 2016), it is essential to understand how the domains of language and
2 cognitive control interact with each other.

3 A major source of information on this interaction comes from experimental
4 studies on single-word language switching (Declerck & Philipp, 2015). Within the
5 wide variety of tasks that have been used to study this phenomenon, a major
6 distinction can be made between tasks that require participants to produce language
7 switches and those that investigate the recognition of visually or auditorily presented
8 language switches (for an overview of these tasks, see Reynolds, Schloffel, &
9 Peressotti, 2016). Language switching in production is often tested using a cued
10 picture naming paradigm. In their seminal study, Meuter and Allport (1999) found
11 that language switches incur a behavioural cost and that the size of this effect depends
12 on the direction of the language switch with a higher cost for switches from second
13 (L2) into first language (L1) (backward switches) than for switches from L1 into L2
14 (forward switches). This phenomenon is referred to as asymmetry in language
15 switching and has been replicated in many later studies (for an overview, see Bobb &
16 Wodniecka, 2013).

17 How does this pattern of language switching performance relate to cognitive
18 control? One theoretical account to explain asymmetry in language switching is
19 derived from the inhibitory control model and suggests that the language switch
20 direction modulates the extent of mental control that is needed to enable the switch
21 (Green, 1998). On a forward switch, much inhibitory control is required to suppress
22 the dominant language. On a subsequent backward switch, this high level of
23 inhibitory control has to be overcome to reactivate the dominant language and this
24 additional reactivation cost is assumed to lead to explain slower performance on a
25 backward switch. Another theoretical account treats asymmetric switch costs as

1 sequential difficulty effects (Schneider & Anderson, 2010). In this view, impaired
 2 performance on a backward switch is interpreted as a spillover effect of the difficulty
 3 of naming pictures in a non-dominant language. As a result of a temporary (so only
 4 affecting performance on the immediately following trial) depletion of control
 5 resources, the difficulty that is encountered when accessing a weaker mental language
 6 set could have an effect on processing the subsequent easier trial. Importantly, the
 7 same difficulty is not experienced on both L1-repeat trials and L2-switch trials,
 8 because naming images in the most proficient language precedes these trials. The
 9 difference between repeat and switch trials is expected to be more modest in L2 than
 10 in L1, because L2-repeat trials are preceded by equally difficult L2-trials, and they are
 11 thus subject to sequential difficulty. Both theoretical accounts relate the asymmetry in
 12 language switching to differences in difficulty or dominance between the languages.
 13 As a consequence, both explanations predict less (or no) asymmetry for balanced
 14 bilinguals whose two language systems are equally dominant than for unbalanced
 15 bilinguals who have one dominant and one non-dominant language system. This
 16 prediction has to some extent been confirmed by studies in balanced and unbalanced
 17 bilinguals (for an overview, see Reynolds et al., 2016).

18 Beside the usage of the cued picture naming paradigm to test the production of
 19 language switches, other studies have investigated the recognition of these switches
 20 by using lexical decision or semantic categorisation tasks. Analogous to the
 21 performance on production tasks, the recognition of language switches incurs a
 22 behavioural cost with slower response latencies on switch than on repeat trials. But, in
 23 contrast to bilingual production tasks, the direction of the switches does not have an
 24 effect on performance on recognition tasks (Macizo, Bajo, & Paolieri, 2012;
 25 Orfanidou & Sumner, 2005; Thomas & Allport, 2000; von Studnitz & Green, 2002).

One possible reason for this discrepancy between bilingual production and recognition tasks is that only the former entails domain-general inhibitory control, as suggested by the Bilingual Interactive Activation model (Dijkstra & van Heuven, 2002; van Heuven, Dijkstra, & Grainger, 1998), which attributes switch costs in bilingual word recognition to a domain-specific control mechanism of language activation. It can be assumed that production, but not recognition tasks involve inhibitory control because only the former generates response competition. The reason for this is that production tasks are typically composed of bivalent stimuli, which means that each stimulus (e.g. a picture) can elicit two responses, or one for each language (for a discussion, see Reynolds et al., 2016). As a result, inhibitory control must be applied to solve this competition between two different responses. Bilingual recognition tasks, on the other hand, are composed of univalent stimuli, meaning that the stimuli (e.g. a word) are coded in a specific language, and thus that these tasks do not necessarily lead to competition between two response sets. This does not mean that modality (recognition or production) and valence (univalent or bivalent) are necessarily conflated, or that it is impossible to untangle which of these two factors is responsible for the asymmetric switch costs. One recent experiment revealed non-symmetric switch costs in bilingual production for both univalent (language-specific number words such as ‘four’) and bivalent (language-nonspecific numerals such as ‘4’) stimuli (Reynolds et al., 2016), which suggests that asymmetry is related to response modality instead of stimulus valence.

In most real-life settings, the distinction between bilingual recognition and production may also correspond to a difference in reliance on response competition. In bilingual recognition, verbal or written input will only activate lexical items from one language, except for interlingual homonyms, or words from two languages having

1 the same spelling or pronunciation but a different meaning (e.g. Durluk, Szewczyk,
 2 Muszynski, & Wodniecka, 2016); in bilingual production, however, the initial stage
 3 of conceptual preparation (Levelt, Roelofs, & Meyer, 1999) may lead to at least two
 4 lexical items (one for each language) competing for activation, except in case of
 5 identical cognates or words from two languages with the same meaning and spelling
 6 or pronunciation (e.g. Costa, Santesteban, & Cano, 2005).

7 A more direct line of evidence on the interaction between domain-general
 8 control and language switching comes from studies in which the same participants
 9 execute tasks of domain-general control and language switching. Analogous to the
 10 ongoing debate on bilingual advantages in cognitive control (e.g. von Bastian et al.,
 11 2016), these studies have generated mixed results. On the one hand, some studies
 12 have suggested strong domain-general involvement in language control by showing
 13 that groups with superior language switching abilities or a higher switching frequency
 14 score better on tasks of domain-general control (Festman & Munte, 2012; Prior &
 15 Gollan, 2011; Verreyt, Woumans, Vandelandotte, Szmalec, & Duyck, 2016;
 16 Woumans, Ceuleers, Van der Linden, Szmalec, & Duyck, 2015); that inhibitory
 17 control predicts switch costs in picture naming (Linck, Schwieter, & Sunderman,
 18 2012); and that training on either domain-general or domain-specific control transfers
 19 into performance in the other domain (Liu, Liang, Dunlap, Fan, & Chen, 2016; Prior
 20 & Gollan, 2013; Zhang, Kang, Wu, Ma, & Guo, 2015). On the other hand, some
 21 studies have suggested limited or no involvement of domain-general control abilities
 22 by showing that the magnitude of switch costs on mixed-language picture naming and
 23 non-linguistic task switch paradigms are not related to each other (Branzi, Calabria,
 24 Boscarino, & Costa, 2016; Calabria, Hernandez, Branzi, & Costa, 2012; Magezi,
 25 Khateb, Mouthon, Spierer, & Annoni, 2012); that domain-general control abilities are

1 not related to grammaticality manipulations in mixed-language connected speech
 2 production (Gollan & Goldrick, 2016); and that domain-general control mechanisms
 3 can be bypassed if switching only occurs when a word is more accessible in the other
 4 language (Kleinman & Gollan, 2016). In a similar vein, three recent studies suggest
 5 that aging has a more profound impact on domain-specific than on domain-general
 6 control abilities (Calabria, Branzi, Marne, Hernandez, & Costa, 2015; Ivanova,
 7 Murillo, Montoya, & Gollan, 2016; Weissberger et al., 2012). Moreover, bilingual
 8 aphasia turns out to have a different impact on domain-general control, as measured
 9 by a flanker task and domain-specific control (Gray & Kiran, 2016).

10 Importantly, the studies mentioned above on the interaction between domain-
 11 general and domain-specific control have so far mostly focused on the overlap
 12 between these two types of inhibitory control as measured by the conflict size on non-
 13 linguistic interference tasks and switch costs in language switching paradigms,
 14 respectively. However, bilingual advantages in cognitive control tend to manifest
 15 themselves more generally on global performance (as a reflection of superior conflict
 16 monitoring skills) than specifically on conflict trials (as a reflection of superior
 17 inhibitory control skills) (Costa et al., 2009; Hilchey & Klein, 2011). Therefore, it is
 18 essential not only to include measures of language production that generate language
 19 competition at the response level and that require inhibitory control to solve this
 20 competition, but also measures of language recognition that involve extensive
 21 monitoring needed to assess which language system to access.

22

23 ***The effects of language experience on language switching and cognitive control***

24 Language proficiency is one of the most important factors to explain
 25 asymmetric switch patterns in mixed-language production tasks. Most studies that

1 reported higher backward than forward switch costs in picture naming had unbalanced
 2 bilinguals as participants (Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova,
 3 2006; Fink & Goldrick, 2015; Jackson, Swainson, Cunnington, & Jackson, 2001;
 4 Meuter & Allport, 1999; Philipp, Gade, & Koch, 2007; Verhoef, Roelofs, & Chwilla,
 5 2009) or tested highly proficient bilinguals in a low proficient third language or a
 6 newly learnt language (Costa et al., 2006; Martin, Strijkers, Santesteban, Escera,
 7 Hartsuiker, & Costa, 2013). These findings suggest that initially higher inhibitory
 8 control requirements related to managing two or more language systems with huge
 9 differences in proficiency levels disappear with increasing proficiency in the low
 10 proficient language. Interestingly, the effect of increasing L2 proficiency on
 11 asymmetry in language switching seems to extend beyond the linguistic domain:
 12 bilinguals with a higher L2 proficiency can switch more easily from a more difficult
 13 to an easier task set as compared to bilinguals with low L2 proficiency (Tse &
 14 Altarriba, 2015); besides, L2 proficiency has been associated with enhanced conflict
 15 resolution and working memory capacity (Tse & Altarriba, 2014). These findings are
 16 in line with some recent studies suggesting that enhanced performance on domain-
 17 general control is related to higher second language proficiency or balanced
 18 bilingualism (Singh & Mishra, 2015; Yow & Li, 2015; but also see von Bastian,
 19 Souza, & Gade, 2015)

20 Measures of language proficiency in each of the languages of a bilingual may
 21 not be sufficient to capture the complex nature of bilinguals' language usage (Yang,
 22 Hartanto, & Yang, 2016). The variability in language switching abilities may be
 23 related to specific patterns of language use. The adaptive control hypothesis (Green &
 24 Abutalebi, 2013) suggests varying language control requirements for the different
 25 conversational contexts that bilinguals may encounter in their daily language use.

This hypothesis has been tested with bilinguals within single-language and dual-language contexts, showing smaller switch costs in task-switching paradigms for bilinguals who use their two languages in the same conversational contexts (Hartanto & Yang, 2016). This effect is possibly mediated by switching frequency because language switches are rare when bilinguals use their two languages in different contexts. In one study where three groups of bilinguals with divergent language switching experiences were compared on cognitive control to a group of monolinguals, the balanced switching bilinguals group turned out to outperform the other non-switching and unbalanced bilingual groups, who did not differ from each other (Verreyt et al., 2016). High adaptability of language control can also be assessed using language tasks. On a trilingual picture naming task, Babcock and Vallesi (2015) found different patterns of $n-2$ repetition costs for the three languages in the four groups they examined, which was assumed to reflect the divergent interactional contexts in which these languages were used by these different groups. Even higher adaptability of language control was found in a study on the effect of domain-general inhibitory control training on asymmetry of language switches in production: only after six training sessions over a one-week period, asymmetry in language switching turned into symmetric language switches (Liu et al., 2016). Again, it is important to stress that studies on the effect of bilingual experience on the development of language control have so far only included production, but no recognition tasks.

The present study

The present study aims to investigate the interaction between the recognition of language switches and domain-general cognitive control abilities in a group of bilinguals with varying levels of second language proficiency and degrees of recent

1 language exposure. Previous studies have suggested that inhibitory control is not
2 involved in recognition tasks due to the absence of asymmetric language switching or
3 slower responding on forward than on backward switch trials (Macizo et al., 2012).
4 However, inhibitory control is only one of the three processes that are part of domain-
5 general control, next to shifting and updating or monitoring (Miyake et al., 2000).
6 Whereas bilingual production tasks require inhibitory processes to solve competition
7 between lexical items from both languages at the response level, it can be assumed
8 that bilingual recognition tasks have high monitoring requirements at the input level
9 because stimuli are presented in both languages and participants thus constantly have
10 to monitor which language system to access in order to respond accurately to the task
11 at hand. The theoretical motivation of this study lies in the assumption that different
12 control mechanisms are at play in bilingual recognition tasks (language input
13 monitoring) compared to bilingual production tasks (response competition) and that
14 this will result in significant correlations with different measures of domain-general
15 control for recognition (monitoring) and production tasks (inhibition) in two
16 languages.

17 This theoretical motivation has driven our choice to select an interference task
18 (i.e. the Simon task) to measure domain-general control, because this type of tasks
19 allows for measuring processes of monitoring (indexed by global performance) and
20 inhibition (indexed by the effect of congruency) at the same time (for a review on
21 using measures of interference tasks such as the Simon task with bilingual
22 participants, see Hilchey & Klein, 2011). The congruency or Simon-effect is caused
23 by stimulus-response interference on incongruent trials, which means that the stimuli
24 on these trials automatically generate a response that must be suppressed (Simon &
25 Rudell, 1967). Throughout the entire task, the participant has to monitor the

possibility of an upcoming stimulus-response conflict because congruent and incongruent trials are evenly distributed and switches are unpredictable. As such, the usage of an interference task gives us the possibility to assess to which of these two processes performance on a bilingual recognition task is most related. One additional motivation for choosing an interference task is that it allows for testing the relationship between switch directionality effects in bilingual language control and domain-general control. Previous research on interference tasks has revealed that the behavioural effects of difficult (or incongruent) trials are smaller when these trials are preceded by another difficult trial than when they follow an easy (or congruent trial) (Blais, Stefanidi, & Brewer, 2014; van Maanen & van Rijn, 2010). Drawing an analogy with language switching, this effect may be considered as a forward switch cost (from an easy to a difficult trial). To test the overlap between various measures of bilingual language control and domain-general control, we will examine if switch directionality effects (both forward and backward switch costs) in both tasks are related to each other.

The first research question we intend to investigate with this study is to what extent language switch costs in either direction (from L1 to L2 and from L2 to L1) on a categorisation task correlate with cognitive control performance. Based on the Inhibitory Control Model (Green, 1998) and the Bilingual Interactive Activation Model (Dijkstra & van Heuven, 2002), we expect switch costs on the categorisation task not to be related to the conflict or congruence effect in the Simon task (as a reflection of inhibitory skills) because unlike production, bilingual categorisation does not involve response competition (Macizo et al., 2012). Instead, we expect switch costs on the categorisation task to be selectively correlated to global performance on the interference task (as a reflection of monitoring skills), which is in line with the

1 bilingual monitoring advantage or the observation of decreased global response times
 2 for bilinguals on interference tasks (Costa et al., 2009). Because it is more effortful to
 3 recognise lexical items from a non-dominant than from a dominant language, the
 4 behavioural effects of the monitor's efficiency are expected to manifest themselves
 5 rather on forward switches (from L1 to L2) than on backward switches (from L2 to
 6 L1).

7 Our second research question is to what extent individual language
 8 background characteristics such as second language proficiency, onset age of second
 9 language acquisition, and recent language exposure contribute to performance on a
 10 bilingual language control task. In line with the adaptive control hypothesis (Green &
 11 Abutalebi, 2013), we expect that individuals with higher proficiency or longer
 12 exposure to a second language may show facilitation in language switching [indicated](#)
 13 [by smaller switch costs on](#) the bilingual categorisation task.

14

15 **Materials and methods**

16

17 ***Participants***

18 A total of 32 Dutch-French bilingual young adults from the Dutch-medium
 19 Vrije Universiteit Brussel in Belgium (14 females; mean age = 20.6 years; $SD = 0.5$
 20 years) were selected for this study. All participants indicated Dutch as their first
 21 language (L1) and French as their second language (L2). They were all first-year
 22 Bachelor's students in an applied linguistics programme with two languages,
 23 including French and one other language (Dutch, English, German or Spanish). They
 24 were tested at the end of the second semester, after eight months of study. During the
 25 weeks of lecture, they had had at least six hours of instruction in French. The other

lectures were taught in Dutch (general courses in linguistics) or in the other language of the programme. Students with lower proficiency in French at the start of the programme received additional instruction in that language to catch up with their peers who had higher proficiency in French. As a result, second language proficiency did not automatically imply higher rates of recent language exposure. All participants had also learnt English from age 12 at school. At the point of examination, for all participants Dutch was the principal language they had been using and still used for education. All participants completed an adapted version of the Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007) in Dutch including questions about the number of languages they spoke, their onset ages of language acquisition for each of these languages, self-reported language proficiency on a 5-point scale, and exposure to their languages in the twelve months preceding the time of investigation (in percentages). Paired samples T-tests on the whole test population revealed highly significant differences with large effect sizes between the first and second language with regards to self-reported language proficiency, $t(31) = 7.54, p < .001, d = 1.33$, and language exposure, $t(31) = 6.15, p < .001, d = 1.09$. Language background information on the group of participants as a whole is given in Table 1.

<Insert Table 1 about here>

Single-language verbal fluency task

This task was included to report an objective score on the participants' productive language ability in their second language. Participants were instructed to name as many words as possible that start with a given phoneme in a one-minute

period. This task had two conditions: Dutch (or L1) and French (or L2). The order of both conditions was counterbalanced across participants. Three phonemes with an equal distribution as onset sound in Dutch and French words were selected from the CELEX database (Baayen, Piepenbrock, & Van Rijn, 1993): /l/, /t/ and /m/. These three phonemes could be presented to the participants in six different orders. The order of presentation was randomly distributed across participants. All spoken instructions were digitally pre-recorded by a Dutch-French bilingual speaker and they were administered to the participants through headphones with a microphone attached. Only L2 scores are reported and used for further analyses because previous research has shown that fluency in L1 suffers if it is performed after L2 in exactly the same version of the verbal fluency task used in this study (Van Assche, Duyck, & Gollan, 2013). Importantly, the same study revealed that non-dominant language production was not affected by prior production of words from the other language. Descriptive statistics about the L2 scores on this task are given in Table 1.

Bilingual categorisation task

The stimuli of the bilingual categorisation task were 156 nouns, that were equally divided over two factors: animacy and language; each taking two levels: animate and inanimate for animacy; and Dutch and French for language. The 156 stimuli thus consisted of 39 Dutch animate nouns; 39 Dutch inanimate nouns; 39 French animate nouns; and 39 French inanimate nouns. All words were selected from the CELEX database (Baayen et al., 1993) and were matched across languages and categories for word length and frequency. Cognates between languages were not included. The stimuli of this task did not contain any translation equivalents, so all presented words were different for the two language conditions. The task was

designed such that language switches were unpredictable and that the same trial type did not occur more than three times in a row. Participants were instructed to respond as quickly as possible to the animacy of the stimulus with a left or right button press. Stimulus-response mapping was counterbalanced across participants: animacy of the stimulus was for half of them linked to a left button press and for the other half to a right button press. Each stimulus was preceded by a fixation cross which remained in the centre of the screen for 500 milliseconds. The stimuli were presented in black Courier font, size 36, for up to 2000 milliseconds in the centre of a white screen or until the participant responded. Apart from the first four trials, which were removed from further analysis, the task contained 76 language repeat trials and 76 language switch trials.

Simon task

The stimuli of the Simon task (Simon & Rudell, 1967) were a red and a green square that were presented at the left or right side of the computer screen. The total number of trials was 156, equally divided according to the colour and location of the stimulus: 39 trials with a red square appearing on the left; 39 trials with the same square appearing on the right; 39 trials with a green square appearing on the left; and 39 trials with the same square appearing on the right. The width of the squares was 10% of the width of the screen and the centre of the squares was positioned vertically on the centre line of the screen and horizontally at 15% and 85% of the width of the screen. Participants were instructed to respond as quickly as possible to the colour of the stimulus with a left or right button press, ignoring the location of the stimulus. Stimulus-response mapping was counterbalanced across participants: a green stimulus was for half of them linked to a left button press and for the other half to a right

1 button press. Each stimulus was preceded by a fixation cross which remained in the
2 centre of the screen for 500 milliseconds. The stimuli were displayed in the centre of
3 a black screen for up to 2000 milliseconds or until the participant responded. On
4 congruent trials (78 trials), the location of the stimulus overlapped with the location of
5 the button press; on incongruent trials (78 trials), the location of the stimulus did not
6 overlap with the location of the button press. The task was designed in such a way
7 that the congruence of the next trial was unpredictable and that the same trial type did
8 not occur more than three times in a row.

9

10 ***Procedure***

11 The bilingual categorisation task and the Simon task were programmed in E-
12 Prime 2 (Psychology Software Tools, Pittsburgh, PA) and implemented on a Dell
13 Latitude E6500 with a 15.4-inch screen. All participants were tested individually in a
14 soundproof experimental cabin on campus. All participants started with the verbal
15 fluency task. The order of the two other tasks was counterbalanced across
16 participants. A practice block of ten trials preceded both experimental tasks to
17 ascertain that the participants had understood the task instructions. All participants
18 obtained the self-defined cutoff score of 80% and could proceed to the actual
19 experimental task.

20

21 **Results**

22

23 ***Bilingual categorisation task***

24 Response times (in milliseconds) and accuracy scores (one for correct trial and
25 zero for incorrect trial) were collected for all 152 trials of this task. Both by-subject

(F1) and by item (F2) analyses were performed. Mean accuracy scores are reported in percentages as a ratio of correct trials to the total number of trials. Response times on incorrect trials and on correct trials with a response time above or below 2.5 standard deviations from the individual mean were removed from further analysis. One-sample Kolmogorov-Smirnov tests were conducted on response times and accuracy scores to test for normality.

A two-way analysis of variance was conducted on mean response times and mean accuracy scores with Language and Type of trial as the within-subject variables, each with two levels (Dutch and French for Language; repeat and switch for Type of trial). We expected main effects of these two variables with higher response times for L2 than L1; and a general switch cost. The interaction effect between these two variables was tested to assess the symmetry of switch costs, with a significant interaction effect taken as an indicator of asymmetric switch costs and no significant interaction effect as an indicator of symmetric switch costs.

As for the by-subject analyses (F1), we found a highly significant main effect of Language on the response times (see Figure 1), $F1(1, 31) = 44.10, p < .001, \eta^2 = .59$, with higher response times on French trials ($M = 853.04; SD = 146.55$) than on Dutch trials ($M = 741.30; SD = 131.33$). We also found a significant main effect of Type of trial, $F1(1, 31) = 6.93, p = .01, \eta^2 = .18$, with higher response times on switch trials ($M = 804.15; SD = 142.76$) than on repeat trials ($M = 790.16; SD = 135.12$). We found no significant interaction effect between the variables Language and Type of trial, $F1(1, 31) = 1.57, p$ ns. The by-item analyses (F2) on response times confirmed the F1 analyses, with a highly significant main effect of Language, $F2(1, 151) = 225.53, p < .001, \eta^2 = .60$; a significant main effect of Type of trial, $F2(1,$

151) = 5.53, $p < .05$, $\eta^2 = .04$; and no significant interaction effect between Language and Type of trial, $F(1, 151) = 1.06$, p ns.

<Insert Figure 1 about here>

As it has been recommended to analyse categorical data that are collected from psycholinguistic tasks with logistic mixed-effects regression modelling (LMER) rather than with analysis of variance (e.g. Ivanova, Salmon, & Gollan, 2014; Jaeger, 2008), we implemented such a model with Language and Trial type as fixed predictors, and Subject and Item as random predictors in the statistical software R (version 3.3.3; The R Foundation for Statistical Computing, 2017). The model had random intercepts and slopes for Subject, and random intercepts for Item. We used contrast coding for the fixed predictors, which means that both languages and types of trial were assigned the numerical values of -0.5 (Dutch for Language, and repeat for Type of trial) and 0.5 (French for Language, and switch for Type of trial). The results from the analysis of variance on the same data can be found in Appendix 1.

<Insert Table 2 about here>

The results from the LMER analyses can be found in Table 2. Only the main effect of Language turned out to be statistically significant, with lower accuracy scores on French trials ($M = 83.37$; $SD = 11.41$) than on Dutch trials ($M = 96.65$; $SD = 2.90$) (see Figure 2). Neither the main effect of Trial Type nor the interaction effect between both variables turned out to be significant.

<Insert Figure 2 about here>

To further investigate the effects of switch directionality, we calculated backward and forward switch costs in terms of response times and accuracy scores. As for response times, the backward switch cost of each individual participant was calculated by subtracting mean response times on L1-repeat trials from mean response times on L1-switch trials; analogously, the forward switch cost was calculated by subtracting mean response times on L2-repeat trials from mean response times on L2-switch trials. As for accuracy scores, the backward switch cost of each individual participant was calculated by subtracting mean accuracy scores on L1-switch trials from mean accuracy scores on L1-repeat trials. The forward switch cost was calculated by subtracting mean accuracy scores on L2-switch trials from mean accuracy scores on L2-repeat trials. The descriptive statistics of these two measures are given in Table 3 and 4. Note that the variability of the forward switch costs as indicated by the standard deviations is much higher than that of the backward switch costs, both on speed and accuracy.

<Insert Table 3 about here>

A paired samples T-test on backward and forward switch costs was added to test the null hypothesis of no difference between both switch types. The null hypothesis could not be rejected, both for response times, $t(31) = 1.25$, p ns., and for accuracy, $t(31) = 1.90$, p ns.

<Insert Table 4 about here>

1

2 We conducted correlational analyses between the switch costs. Significant
 3 correlations were only found between backward and forward switch costs in terms of
 4 response times, $r(32) = -.43, p < .05$, and between backward switch costs in terms of
 5 response times and accuracy scores, $r(32) = -.36, p < .05$, which may be indicative of
 6 a speed-accuracy trade-off when it comes to switching from L2 into L1. No other
 7 correlations were significant.

8

9 ***Simon task***

10 Response times (in milliseconds) and accuracy scores (one for correct trial and
 11 zero for incorrect trial) were collected for all 156 trials of this task. Mean accuracy
 12 scores are reported in percentages as a ratio of correct trials to the total number of
 13 trials. Response times on incorrect trials were removed from further analysis. One-
 14 sample Kolmogorov-Smirnov tests were conducted on response times and accuracy
 15 scores to test for normality.

16 The statistical analysis of the Simon task was performed as closely as possible
 17 to that of the bilingual categorisation task. Hence, a two-way analysis of variance was
 18 conducted on mean response times and mean accuracy scores with Congruency and
 19 Type of trial as the within-subject variables, each with two levels (congruent and
 20 incongruent for Congruency; repeat and switch for Type of trial). We expected a main
 21 effect of Congruency (Simon & Rudell, 1967). The second within-subject variable
 22 was added to our model to assess potential similarities between the language
 23 categorisation task and the Simon task. If domain-general inhibitory control as
 24 measured by the Simon task is a good proxy of domain-specific (language) control on
 25 a bilingual categorisation task, switching back and forth between easier (congruent)

1 trial and more difficult (incongruent) trials may be similar to switching between
 2 languages with varying proficiency levels, and thereby generating comparable switch
 3 costs. In addition, the interaction effect between both within-subject variables was
 4 added to explore potential similarities between the direction of congruence switches
 5 in the Simon task and the direction of language switches in the bilingual
 6 categorisation task.

7 With respect to the response times, we found a highly significant effect of
 8 Congruency, $F(1, 31) = 29.21, p < .001, \eta^2 = .49$, with higher response times on
 9 incongruent trials ($M = 437.62; SD = 53.24$) than on congruent trials ($M = 423.08; SD$
 10 $= 56.19$). We also found a highly significant effect of Type of trial, $F(1, 31) = 121.90$,
 11 $p < .001, \eta^2 = .80$, with higher response times on switch trials ($M = 445.01; SD =$
 12 56.64) than on repeat trials ($M = 415.68; SD = 52.79$). We found no significant
 13 interaction effect between the variables Congruency and Type of trial, $F(1, 31) = .31$,
 14 p ns.

15 The accuracy scores on the Simon task were not normally distributed due to a
 16 ceiling effect. Therefore, two Wilcoxon signed-rank tests were conducted, first
 17 comparing accuracy scores on congruent and incongruent trials (effect of
 18 Congruency); then comparing accuracy scores on switch and repeat trials (effect of
 19 Type of trial). We found a significant effect of Congruency, $Z = 4.33, p < .001$, with a
 20 higher median accuracy score for repeat trials (100; range: 96-100) than for switch
 21 trials (98; range: 88-100). We did not find a significant effect of Congruency, $Z = .82$,
 22 p ns.

23 We further investigated the effects of switch directionality in the Simon task
 24 by calculating forward and backward switch costs, again analogous to the analysis of
 25 the bilingual categorisation task, and in line with the observed main effects of switch

1 on mean response times and accuracy scores of the Simon task. As for response times,
 2 the backward switch cost of each individual participant was calculated by subtracting
 3 mean response times on congruent-repeat trials from mean response times on
 4 congruent-switch trials; analogously, the forward switch cost was calculated by
 5 subtracting mean response times on incongruent-repeat trials from mean response
 6 times on incongruent-switch trials. As for accuracy scores, the backward switch cost
 7 of each individual participant was calculated by subtracting mean accuracy scores on
 8 congruent-switch trials from mean accuracy scores on congruent-repeat trials. The
 9 forward switch cost was calculated by subtracting mean accuracy scores on
 10 incongruent-switch trials from mean accuracy scores on incongruent-repeat trials.
 11 One sample T-tests against zero revealed that the backward switch costs were
 12 significant with large effect sizes in terms of response times, $t(31) = 8.06, p < .001, d = 1.42$,
 13 and accuracy scores, $t(31) = 4.52, p < .001, d = 0.80$; the forward switch costs
 14 were also significant with moderate to large effect sizes in terms of response times,
 15 $t(31) = 9.57, p < .001, d = 1.69$, and accuracy scores, $t(31) = 3.49, p < .01, d = 0.62$.
 16

17 ***Correlations among measures of language and domain-general (cognitive) control***

18 To test for dependency between measures of domain-specific (language)
 19 control and domain-general control, we conducted Pearson's correlational analyses
 20 among response times and accuracy scores on the bilingual categorisation task and the
 21 Simon task. We distinguish between measures at three levels: first, we took into
 22 account global response times on each task; second, we looked at language and
 23 switch-cost differences (for the bilingual categorisation task) and at congruency and
 24 switch-cost differences (for the Simon task); third, we considered the
 25 forward/backward switch costs for both tasks. Language differences on the bilingual

categorisation task were calculated by subtracting mean response times (or accuracy rates) on L1 trials from the same measure on L2 trials. Congruency differences on the Simon task were calculated by subtracting mean response times (or accuracy rates) on congruent trials from the same measure on incongruent trials. Switch-cost differences were calculated by subtracting mean response times (or accuracy rates) on repeat trials from the same measure on switch trials for both tasks. In total, we conducted correlational analyses on five measures of the bilingual categorisation task and the equivalent five measures of the Simon task, which resulted in 25 (5 times 5) correlation coefficients for response times and for accuracy scores. The results of the analyses on the response times are given in Table 5. The same correlational analyses were conducted on the accuracy scores, but none of the correlations turned out to be significant.

<Insert Table 5 about here>

Correlations among measures of language control and language background variables

To test the adaptive control hypothesis, we conducted Pearson's correlational analyses among measures of language control and language background characteristics (see Table 1). Correlation coefficients are given in Table 6.

As all our participants also reported proficiency in English as their third language, we conducted Pearson's correlational analyses between their self-reported proficiency in that language and their exposure to it, and the measures of language control to assess if, and to what extent, their third language skills could have impacted their language control skills, but none of these correlations achieved significance.

1

2 <Insert Table 6 about here>

3

4 **Discussion**

5 The present study investigated domain-general control involvement in
 6 language switching on a bilingual categorisation task. A consideration of the
 7 relationship between second language proficiency, onset age of second language
 8 acquisition, and recent language exposure and language control measures tested the
 9 adaptive control hypothesis. The results showed that domain-general control was
 10 critically involved in switches from the dominant into the non-dominant language.
 11 Moreover, the size of these forward language switches depended on recent L2
 12 exposure and not on the onset age of acquisition or second language proficiency,
 13 which is indicative of short-term adaptability of language control to changing
 14 demands from the language environment.

15

16 ***Domain-general control and language switching***

17 The present study used a bilingual categorisation task with unpredictable
 18 language switches to assess language switching in bilingual participants. In line with
 19 all studies on non-voluntary language switching (e.g. Gollan & Ferreira, 2009; Meuter
 20 & Allport, 1999), this paradigm generated switch costs in processing speed. These
 21 switch costs were symmetric, which means no differences in the size of the language
 22 switches were seen between backward (switches into L1) and forward (switches into
 23 L2) switches. This finding is in line with all previous studies on language switching in
 24 categorisation tasks (for an overview, see Reynolds et al., 2016) and it adds to the
 25 idea that the processes of producing and recognising language switching are

1 fundamentally different in that the former generates (in some instances) asymmetric
2 switches, while the latter results in switching symmetry. Possibly, this difference can
3 be related to the absence of competition between response sets on language switches
4 in tasks with univalent stimuli (see Green, 1998).

5 Unlike previous studies on language switching in recognition tasks (e.g.
6 Macizo et al., 2012; Orfanidou & Sumner, 2005), the present study added a measure
7 of domain-general inhibitory control to the test battery in order to investigate the
8 interaction between language switching and domain-general control abilities.
9 Crucially, we reported a dependency between global response times on a Simon task
10 and several measures of the bilingual categorisation task. A relationship was found
11 between overall performance (in terms of global response times) on the bilingual
12 categorisation task and on the Simon task, which suggests that these two tasks rely on
13 similar sustained control requirements. Indeed, both tasks share a few characteristics:
14 they are composed of an equal number of easy and more difficult trials, and they
15 require switching between these two trial types on an unpredictable basis. This
16 finding is important, because the bilingual advantage in cognitive control manifests
17 itself more often on global response times than on specific trial types of interference
18 or conflict tasks (Hilchey & Klein, 2011). The observed dependency between a
19 measure of sustained language control and global response times of a domain-general
20 task of cognitive control suggests that this bilingual advantage on global response
21 times is related to the efficiency of recognising language switches.

22 More fine-grained analyses allowed us to achieve a more detailed
23 understanding of this interaction: first, the global response times on the Simon task
24 were specifically related to switch costs and not to differences between L1 and L2
25 processing (main effect of language); second, the global response times were

1 specifically related to forward- and not to backward-switches, which means that
2 people who are globally faster on the Simon task only have smaller costs when they
3 switch into their L2 than into their L1. These two findings imply that sustained
4 domain-general control abilities do not attenuate the effect of differences in language
5 proficiency levels, as measured by the main effect of language, but that they rather
6 have an impact on the ability to shift between two mental language sets. More
7 specifically, sustained domain-general control abilities seem to be related to the
8 ability to shift from a dominant to a weaker mental language set.

9 Apart from these significant correlations between language control and
10 domain-general cognitive control, we could not find any relationship between the
11 congruency effect in the Simon task and measures of language control in recognition.
12 As such, the results from our study are different from those of a previous study on the
13 interaction between inhibitory control and switch costs in bilingual picture naming
14 that found significant contributions from the size of the Simon effect to switch costs
15 from and into L1 (Linck et al., 2012). Again, we suggest that the absence of
16 competition between response sets on language switches in a recognition task could
17 explain this difference between producing and recognising language switches. At the
18 same time, we acknowledge that many studies on bilingual language production could
19 not find a significant correlation with measures of domain-general inhibitory control
20 as indexed by switch costs in a task-switching paradigm (Declerck & Philipp, 2015)
21 and it remains open for further study if these differences between studies are related
22 to the specific tasks being used for testing this relationship (e.g. Simon task versus a
23 task-switching paradigm) or if they represent a crucial difference between bilingual
24 language production and recognition. With regards to the ongoing discussion on
25 domain-generality of control abilities (e.g. Calabria et al., 2012; Gollan & Goldrick,

2016), our results prompt a nuanced view on the matter. On the one hand, the findings from the present study are in line with previous studies that could not find any correlation between equivalent control measures in domain-specific linguistic and domain-general cognitive tasks (e.g. Calabria et al., 2012; Magezi et al., 2012), even if these two tasks are designed in such a way that they share as many characteristics as possible (e.g. Branzi et al., 2016). Indeed, we did not detect a dependency between switch costs in the bilingual categorisation task and in the Simon task; nor did we find any correlation between backward and forward switch costs in these two tasks. On the other hand, our findings are compatible with studies that show domain-general involvement in language switching performance (e.g. Verreyt et al., 2016; Woumans et al., 2015). Interestingly, one previous study reported that mixing costs on a productive language switching task were only correlated to global response times of the Simon task (Paap & Greenberg, 2013), a finding which is comparable to the one reported in our study on language switching in a recognition task. Taken together, the absence of direct correlations among equivalent measures in domain-specific language and domain-general cognitive control does not imply that there is no overlap between the two domains. Our results suggest that this overlap between language and domain-general control may manifest itself by a correlation between two measures that are not equivalent across domains, such as global response times on the Simon task and the switch effect in a bilingual recognition task.

The results of this study cannot be easily integrated into current theories of language switches in production (Green, 1998; Schneider & Anderson, 2010), but urge the need for a specific framework on language switches in recognition. The inhibitory control model (Green, 1998) suggests inhibitory control involvement in switching from L2 into L1; a hypothesis which seems to be corroborated by the

previously reported interaction between the Simon effect and backward switching in mixed-language picture naming (Linck et al., 2012). However, we did not find the same correlation on a bilingual categorisation task. Domain-general inhibitory control as measured by performance on the Simon task was not related to backward switch costs, but only to forward switch costs. Thus, from our understanding the inhibitory control cannot account for this pattern. The same applies to the sequential difficulty hypothesis (Schneider & Anderson, 2010), which suggests increased switch costs after difficult (in this context, L2) trials. Again, this theoretical framework can explain the difficulty of switching from an L2 into a L1 or the difficulty of repeating a difficult trial, but it cannot explain an interaction between L2-switches and domain-general control because L2-switches follow easy (L1-)trials.

A better understanding of the interaction between global response times on the Simon task and bilingual language processing can be achieved by considering the impressive amount of studies on a so-called bilingual advantage in Simon task performance (for a recent review, see Zhou & Krott, 2016). While some studies have revealed bilingual advantages on the conflict effect in non-verbal conflict tasks specifically (Bialystok et al., 2008; Bialystok et al., 2005; Bialystok, Craik, Klein, & Viswanathan, 2004; Poarch & van Hell, 2012; Salvatierra & Rosselli, 2011; Tse & Altarriba, 2014), others have found a combination of overall better performance and a reduced conflict effect (Bialystok, Craik, & Ryan, 2006; Costa, Hernandez, & Sebastian-Galles, 2008) or only overall better performance (Bialystok, 2006; Coderre & van Heuven, 2014; Costa et al., 2009; Martin-Rhee & Bialystok, 2008; Struys et al., 2015). Interestingly, overall better performance for bilinguals on the Simon task is only found in high-monitoring conditions with an equal percentage of congruent and incongruent trials (see also Costa et al., 2009), which is exactly the same version as

1 the one used in the present study. Our results suggest that an L2-switch in a bilingual
2 categorisation task taps into the same monitoring requirements as a Simon task with
3 as many congruent as incongruent trials.

4 Our results support instead a monitoring account of language switching in
5 recognition tasks. In this account, the monitor has the same function as in a Simon
6 task in that it keeps track of the probability of a switch on the subsequent trial based
7 on the congruency of the previous trials and it regulates the activation level of the two
8 mental language systems accordingly. One of the major roles of this monitor is to
9 alleviate the behavioural costs associated with these switches (Botvinick, Braver,
10 Barch, Carter, & Cohen, 2001); as a result, the behavioural effects of the monitor's
11 efficiency are expected to manifest themselves most on the trial type that creates the
12 largest behavioural cost. On a language task with mixed-language stimuli, the most
13 challenging trials are the switch trials, and arguably even more so the switches from
14 easy trials (words in the dominant language) to difficult trials (words in the non-
15 dominant language) than the switches in the inverse direction. Therefore, individuals
16 with a more efficient monitor will show a lower switch effect, especially on switches
17 from L1 into L2. The monitor is assumed to operate on a trial-by-trial basis, which
18 means that it assesses the need for adapting the activation level of each mental
19 language system based on the distribution of these two systems over the previous
20 trials. In a mixed-language task, the probability of the next trial being a costly L2-
21 switch is evidently higher on an L1-trial (and even more so on a L1-repeat trial) than
22 on an L2-trial (in which case it is zero). Thus, on an L1-repeat trial, the monitor
23 signals a high probability of an upcoming L2-switch and increases the activation level
24 of the L2 mental system. As a result, more strongly activated L2-items may enter into
25 competition with the L1-items, which may slow down performance on L1-repeat

1 trials, as shown by the negative correlation between forward and backward switching
 2 costs. On an L2-switch trial, in contrast, the monitor decreases the activation levels of
 3 the L2 mental system because of the impossibility of a subsequent L2-switch. This
 4 leads to overall higher error rates on L2-repeat trials; and in some individuals, this can
 5 lead to higher response latencies on L2-switch than L2-repeat trials.

6 The absence of correlations between equivalent backward and forward switch
 7 measures of both tasks suggests that the monitor has a different function when
 8 stimulus-response compatibility is being manipulated, as is the case in the Simon task.
 9 On backward and forward switch trials in a mixed-language recognition task,
 10 participants have to switch between two mental language sets, composed of distinct
 11 stimuli (words in L1 and L2). Switch trials in the Simon task, however, do not involve
 12 a switch between two stimuli sets, but between an automatic response and the
 13 suppression of that response. In fact, our version of the Simon task was only
 14 composed of two different stimuli of the same difficulty (a colored square), that could
 15 appear on both sides of the presentation screen. As a result, the monitor's function
 16 was not to adapt the activation levels of these stimuli (as during the categorisation
 17 task), but to assess the probability of an upcoming stimulus-response conflict. While
 18 the usage of different stimuli for each of the two languages in the recognition task
 19 supposedly led to trial-level monitoring effects, the usage of the same stimuli for both
 20 congruent and incongruent trials only resulted in global monitoring effects. This
 21 means that monitoring requirements were constant throughout the entire Simon task
 22 which consisted of an equal number of congruent and incongruent trials, and
 23 unpredictable switches between both trial types.

24 The monitoring account suggests a connection between the monitoring
 25 requirements of a task in terms of the distribution of the trial types and the

1 engagement of the monitor, leading to behavioural effects on specific trial types.
2 Therefore, one of the main limitations of the present study is that we only included
3 two experimental tasks with an equal distribution of switch and repeat trials (for the
4 language task) and of congruent and incongruent trials (for the Simon task). The need
5 for monitoring in this type of tasks is particularly high; hence, we suggest that a
6 manipulation of this distribution could change the observed effects. The monitoring
7 account of language switching in recognition tasks makes two testable predictions
8 with regard to these effects: first, it predicts significantly higher forward switching
9 costs and no negative correlation between forward and backward switching costs on
10 language switching tasks with lower monitoring requirements (for instance, with only
11 25% of L2-trials); second, it assumes no relationship between forward switching costs
12 in language recognition tasks and global response times on low-monitoring versions
13 of the Simon task with an unequal distribution of congruent and incongruent trials (for
14 instance, with only 25% of incongruent trials).

15 Further studies should investigate whether the proposed monitoring account
16 only applies to recognition or also to mixed-language production tasks. Interestingly,
17 some of the previous studies on bilingual production that could not find a relation
18 between switch costs in tasks of language and domain-general cognitive control have
19 reported significant correlations between mixing costs in these two domains (Cattaneo
20 et al., 2015; Prior & Gollan, 2013). While switch costs are generally seen as indices of
21 reactive or inhibitory control, mixing costs are considered to reflect proactive control
22 or monitoring. Based on these findings, it can thus be assumed that monitoring and
23 not inhibitory control is the overlapping mechanism between the two domains.

24

1 *The effects of language proficiency and exposure on language switching and*
 2 *cognitive control*

3 The results from this study lend some support to the adaptive control
 4 hypothesis (Green & Abutalebi, 2013), which predicts adaptability of language
 5 control processes in response to changing interactional contexts. A crucial question in
 6 this respect is whether the strength of language control networks in individual
 7 language users shows short-term adaptation as a function of the dynamics of language
 8 use patterns or rather long-term adaptation related to the length of active bilingualism.
 9 Interestingly, our results show crucial differences in the impact of several language
 10 background variables on the speed of L2 word processing, and on the switch costs. In
 11 line with our hypothesis, the L2-effect on response times in the bilingual
 12 categorisation task was significantly and positively correlated with the age of L2
 13 acquisition; and significantly and negatively correlated with self-rated L2 proficiency,
 14 L2 exposure, and L2 verbal fluency. In contrast to our hypothesis, the switch effect on
 15 response times showed a selective correlation with L2 exposure but not with any of
 16 the other language background measures. In fact, individuals with higher levels of
 17 recent exposure to their second language showed a lower cost of switching from the
 18 dominant into the non-dominant language than those with lower exposure to the
 19 language. The remarkably selective correlation with exposure may be explained by
 20 the specific characteristics of our group of participants: as students of French
 21 linguistics in a bilingual city, they come from various linguistic situations at home. In
 22 order for those students with lower skills in French to catch up with their near-native
 23 peers, additional foreign language classes were strongly encouraged, as a result of
 24 which students with lower levels of second language proficiency or a later onset age
 25 of second language acquisition may still show a higher percentage of recent language

1 exposure. Crucially, the size of the forward switch cost thus did not depend on the
2 onset age of acquisition or level of second language proficiency but on the exposure
3 to the language over the previous year, suggesting high adaptability of this language
4 control ability.

5 These results are in line with previous studies showing an interaction between
6 patterns of language use and cognitive control (Hartanto & Yang, 2016; Verreyt et al.,
7 2016; Yang et al., 2016). Remarkably, these studies have tested the adaptive
8 (language) control hypothesis by investigating how bilinguals process domain-general
9 control tasks. In line with the results of the present study, we suggest that these effects
10 can be explained by domain-general involvement in language switching, as revealed
11 by the dependency between forward language switching costs and global response
12 times on the Simon task. One of the limitations of the current study is that domain-
13 specific and domain-general control abilities were measured at one time point only. A
14 longitudinal research design with an experimental manipulation of language exposure
15 in two or more groups could reveal if domain-general control abilities are indeed
16 highly responsive to changes in the linguistic environment.

17

18 **Conclusion**

19 The present study collected measures of domain-general cognitive and
20 domain-specific language control in a sample of bilingual young adults with varying
21 levels of second language proficiency, onset ages of acquisition, and exposure rates.
22 Our results show domain-general monitoring involvement in specific components of
23 language switching performance, and a contribution of language exposure to these
24 specific language control measures. The present study thus adds to a growing body
25 of literature on the plasticity of control functions in the bilingual mind. We believe

1 that the field of cognitive control in bilinguals may benefit from these research
2 designs because they can reveal exactly which aspects of the bilingual experience rely
3 on domain-general control and to what extent these functions can be trained as a
4 function of language experience.

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

1 Table 1. *Language background characteristics of participants*

	L1-Dutch	L2-French
Onset age of acquisition		
M (SD)	0.00 (0.00)	3.47 (4.59)
Median (range)	0 (0 - 0)	0 (0 - 10)
Self-rated proficiency		
M (SD)	4.94 (0.23)	3.86 (0.76)
Median (range)	5 (4 - 5)	4 (3 - 5)
Recent exposure		
M (SD)	51.22 (4.54)	36.44 (9.74)
Median (range)	50 (41 - 62)	36 (22 - 53)
Verbal fluency		
M (SD)	*	8.00 (3.48)
Median (range)	*	8 (3 - 15)

2 Note: Onset age of acquisition is given in years. Self-rated proficiency was given on a
3 5-point scale ranging from 1 (not proficient) to 5 (native proficiency), for each
4 language ability separately (listening, speaking, reading and writing). Only the mean
5 score is given. Recent exposure to each of the languages during the year preceding the
6 time of investigation was given in percentages. Verbal fluency was assessed as
7 number words per minute. *Due to language order effects in the verbal fluency task,
8 only L2 scores are reported and used for further analysis.

10

11

12

13

14

15

16

17

18

19

20

21

22

Table 2. *Results of LMER analyses on accuracy data from the mixed-language categorisation task.*

Fixed predictor	<i>Estimate</i>	<i>SE</i>	<i>Wald Z</i>	<i>p</i>
Language	-.13	.02	-6.57	<.001
Type of trial	-.02	.01	1.12	.27
Language * Type of trial	.03	.02	1.32	.19

SE = standard error.

1 Table 3. *Mean backward and forward switch costs on the categorisation and Simon*
2 *task in milliseconds with standard deviations between brackets.*

3

Bilingual	Backward switch cost	23.79 (38.72)
	Forward switch cost	4.13 (65.17)
categorisation task	Backward switch cost	30.51 (21.41)
	Forward switch cost	28.15 (16.64)
Simon task		

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

Table 4. Mean backward and forward switch costs on the categorisation and Simon task in percentages of correct responses with standard deviations between brackets.

Bilingual categorisation task	Backward switch cost	0.32	(3.62)
	Forward switch cost	-2.58	(8.32)
Simon task	Backward switch cost	2.79	(3.49)
	Forward switch cost	2.82	(4.57)

1 Table 5. *Correlation coefficients among measures of domain-specific (language)*
 2 *control and domain-general (cognitive) control in terms of speed of processing.*
 3

Measure of language control	Measure of cognitive control	Correlation coefficient
Global RT	Global RT	.68**
	Congruency difference	-.33
	Switch-cost difference	-.01
	Backward switch cost	.11
	Forward switch cost	.08
Language difference	Global RT	.03
	Congruency difference	.12
	Switch-cost difference	-.16
	Backward switch cost	.07
	Forward switch cost	-.27
Switch-cost difference	Global RT	.46**
	Congruency difference	.14
	Switch-cost difference	.17
	Backward switch cost	.42*
	Forward switch cost	-.05
Backward switch cost	Global RT	-.01
	Congruency difference	-.07
	Switch-cost difference	.08
	Backward switch cost	.21
	Forward switch cost	.24
Forward switch cost	Global RT	.42*
	Congruency difference	.16
	Switch-cost difference	.12
	Backward switch cost	.26
	Forward switch cost	-.19

4 L2 = second language; * $p < .05$; ** $p < .01$; $N = 32$

5

6

7

8

9

10

11

12

13

Table 6. *Correlation coefficients among language background characteristics and measures of domain-specific (language) control in terms of speed of processing.*

Measure of language control	Language background characteristic	Correlation coefficient
Global RT	Onset age of L2 acquisition	.32
	Self-reported L2 proficiency	.05
	L2 exposure	-.15
	L2 verbal fluency	-.21
Language difference	Onset age of L2 acquisition	.70**
	Self-reported L2 proficiency	-.64**
	L2 exposure	-.77**
	L2 verbal fluency	-.37*
Switch-cost difference	Onset age of L2 acquisition	.05
	Self-reported L2 proficiency	-.29
	L2 exposure	-.35*
	L2 verbal fluency	-.02
Backward switch cost	Onset age of L2 acquisition	.18
	Self-reported L2 proficiency	.11
	L2 exposure	.22
	L2 verbal fluency	.14
Forward switch cost	Onset age of L2 acquisition	-.06
	Self-reported L2 proficiency	-.33
	L2 exposure	-.46**
	L2 verbal fluency	-.10

L2 = second language; * $p < .05$; ** $p < .01$; $N = 32$

1 *Appendix 1. Results from the two-way analysis of variance on accuracy scores of the*
2 *mixed-language categorisation task.*

3
4 As for the by-subject analyses (F1), we found a highly significant effect of Language
5 on the accuracy scores (see Figure 2), $F1(1, 31) = 45.83, p < .001, \eta^2 = .60$; but we
6 found no main effect of Type of trial. We found a nearly significant interaction effect
7 between the variables Language and Type of trial, $F1(1, 31) = 3.62, p = .07, \eta^2 =$
8 $.10$. The by-item analyses (F2) on response times confirmed the F1 analyses, with a
9 highly significant main effect of Language, $F2(1, 151) = 116.11, p < .001, \eta^2 = .52$;
10 no significant main effect of Type of trial, $F2(1, 151) = 0.84, p \text{ ns.}$; and no significant
11 interaction effect between Language and Type of trial, $F2(1, 151) = 1.73, p \text{ ns.}$
12

References

- Abutalebi, J., & Green, D. W. (2008). Control mechanisms in bilingual language production: Neural evidence from language switching studies. *Language and Cognitive Processes*, 23(4), 557-582. doi:10.1080/01690960801920602
- Baayen, R. H., Piepenbrock, R., & Van Rijn, H. (1993). *The CELEX lexical database (CD-ROM)*. Philadelphia: University of Pennsylvania, Linguistic Data Consortium.
- Babcock, L., & Vallesi, A. (2015). Language control is not a one-size-fits-all languages process: evidence from simultaneous interpretation students and the n-2 repetition cost. *Frontiers in Psychology*, 6. doi:10.3389/fpsyg.2015.01622
- Bialystok, E. (2006). Effect of bilingualism and computer video game experience on the Simon task. *Canadian Journal of Experimental Psychology-Revue Canadienne De Psychologie Experimentale*, 60(1), 68-79. doi:10.1037/cjep2006008
- Bialystok, E., Craik, F., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology-Learning Memory and Cognition*, 34(4), 859-873. doi:10.1037/0278-7393.34.4.859
- Bialystok, E., Craik, F. I. M., Grady, C., Chau, W., Ishii, R., Gunji, A., & Pantev, C. (2005). Effect of bilingualism on cognitive control in the Simon task: evidence from MEG. *Neuroimage*, 24(1), 40-49. doi:10.1016/j.neuroimage.2004.09.044
- Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging*, 19(2), 290-303. doi:10.1037/0882-7974.19.2.290
- Bialystok, E., Craik, F. I. M., & Ryan, J. (2006). Executive control in a modified antisaccade task: Effects of aging and bilingualism. *Journal of Experimental*

- 1 *Psychology-Learning Memory and Cognition*, 32(6), 1341-1354. doi:10.1037/0278-
2 7393.32.6.1341
- 3 Blais, C., Stefanidi, A., & Brewer, G. A. (2014). The Gratton effect remains after
4 controlling for contingencies and stimulus repetitions. *Frontiers in Psychology*, 5, 1-
5 11. doi:10.3389/fpsyg.2014.01207
- 6 Bobb, S. C., & Wodniecka, Z. (2013). Language switching in picture naming: What
7 asymmetric switch costs (do not) tell us about inhibition in bilingual speech planning.
8 *Journal of Cognitive Psychology*, 25(5), 568-585.
9 doi:10.1080/20445911.2013.792822
- 10 Bobb, S. C., Wodniecka, Z., & Kroll, J. F. (2013). What bilinguals tell us about
11 cognitive control: Overview to the special issue. *Journal of Cognitive Psychology*,
12 25(5), 493-496. doi:10.1080/20445911.2013.822724
- 13 Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001).
14 Conflict monitoring and cognitive control. *Psychological Review*, 108(3), 624-652.
15 doi:10.1037//0033-295x.108.3.624
- 16 Branzi, F. M., Calabria, M., Boscarino, M. L., & Costa, A. (2016). On the overlap
17 between bilingual language control and domain-general executive control. *Acta*
18 *Psychologica*, 166, 21-30. doi:10.1016/j.actpsy.2016.03.001
- 19 Calabria, M., Branzi, F. M., Marne, P., Hernandez, M., & Costa, A. (2015). Age-
20 related effects over bilingual language control and executive control. *Bilingualism-*
21 *Language and Cognition*, 18(1), 65-78. doi:10.1017/s1366728913000138
- 22 Calabria, M., Hernandez, M., Branzi, F. M., & Costa, A. (2012). Qualitative
23 differences between bilingual language control and executive control: evidence from
24 task-switching. *Frontiers in Psychology*, 3. doi:10.3389/fpsyg.2011.00399

- 1 Cattaneo, G., Calabria, M., Marne, P., Gironell, A., Abutalebi, J., & Costa, A. (2015).
2 The role of executive control in bilingual language production: A study with
3 Parkinson's disease individuals. *Neuropsychologia*, 66, 99-110.
4 doi:10.1016/j.neuropsychologia.2014.11.006
- 5 Coderre, E. L., & van Heuven, W. J. B. (2014). The effect of script similarity on
6 executive control in bilinguals. *Frontiers in Psychology*, 5.
7 doi:10.3389/fpsyg.2014.01070
- 8 Costa, A., Hernandez, M., Costa-Faidella, J., & Sebastian-Galles, N. (2009). On the
9 bilingual advantage in conflict processing: Now you see it, now you don't. *Cognition*,
10 113(2), 135-149. doi:10.1016/j.cognition.2009.08.001
- 11 Costa, A., Hernandez, M., & Sebastian-Galles, N. (2008). Bilingualism aids conflict
12 resolution: Evidence from the ANT task. *Cognition*, 106(1), 59-86.
13 doi:10.1016/j.cognition.2006.12.013
- 14 Costa, A., & Santesteban, M. (2004). Lexical access in bilingual speech production:
15 Evidence from language switching in highly proficient bilinguals and L2 learners.
16 *Journal of Memory and Language*, 50(4), 491-511. doi:10.1016/j.jml.2004.02.002
- 17 Costa, A., Santesteban, M., & Cano, A. (2005). On the facilitatory effects of cognate
18 words in bilingual speech production. *Brain and Language*, 94(1), 94-103.
19 doi:10.1016/j.bandl.2004.12.002
- 20 Costa, A., Santesteban, M., & Ivanova, I. (2006). How do highly proficient bilinguals
21 control their lexicalization process? Inhibitory and language-specific selection
22 mechanisms are both functional. *Journal of Experimental Psychology-Learning*
23 *Memory and Cognition*, 32(5), 1057-1074. doi:10.1037/0278-7393.32.5.1057

- 1 Declerck, M., & Philipp, A. M. (2015). A review of control processes and their locus
2 in language switching. *Psychonomic Bulletin & Review*, 22(6), 1630-1645.
3 doi:10.3758/s13423-015-0836-1
- 4 Dijkstra, T., & van Heuven, W. J. B. (2002). The architecture of the bilingual word
5 recognition system: From identification to decision. *Bilingualism-Language and*
6 *Cognition*, 5(3), 175-197. doi:10.1017/s1366728902003012
- 7 Durlík, J., Szewczyk, J., Muszynski, M., & Wodniecka, Z. (2016). Interference and
8 Inhibition in Bilingual Language Comprehension: Evidence from Polish-English
9 Interlingual Homographs. *Plos One*, 11(3). doi:10.1371/journal.pone.0151430
- 10 Festman, J., & Munte, T. F. (2012). Cognitive control in Russian-German bilinguals.
11 *Frontiers in Psychology*, 3. doi:10.3389/fpsyg.2012.00115
- 12 Fink, A., & Goldrick, M. (2015). Pervasive benefits of preparation in language
13 switching. *Psychonomic Bulletin & Review*, 22(3), 808-814. doi:10.3758/s13423-014-
14 0739-6
- 15 Garbin, G., Sanjuan, A., Forn, C., Bustamante, J. C., Rodriguez-Pujadas, A., Belloch,
16 V., . . . Avila, C. (2010). Bridging language and attention: Brain basis of the impact of
17 bilingualism on cognitive control. *Neuroimage*, 53(4), 1272-1278.
18 doi:10.1016/j.neuroimage.2010.05.078
- 19 Gollan, T. H., & Ferreira, V. S. (2009). Should I Stay or Should I Switch? A Cost-
20 Benefit Analysis of Voluntary Language Switching in Young and Aging Bilinguals.
21 *Journal of Experimental Psychology-Learning Memory and Cognition*, 35(3), 640-
22 665. doi:10.1037/a0014981
- 23 Gollan, T. H., & Goldrick, M. (2016). Grammatical constraints on language
24 switching: Language control is not just executive control. *Journal of Memory and*
25 *Language*, 90, 177-199. doi:10.1016/j.jml.2016.04.002

- 1 Gray, T., & Kiran, S. (2016). The relationship between language control and
2 cognitive control in bilingual aphasia. *Bilingualism-Language and Cognition*, 19(3),
3 433-452. doi:10.1017/s1366728915000061
- 4 Green, D. W. (1998). Mental control of the bilingual lexico-semantic system.
5 *Bilingualism: Language and Cognition*, 1(2), 67-81.
6 doi:10.1017/s1366728998000133
- 7 Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive
8 control hypothesis. *Journal of Cognitive Psychology*, 25(5), 515-530.
9 doi:10.1080/20445911.2013.796377
- 10 Hartanto, A., & Yang, H. (2016). Disparate bilingual experiences modulate task-
11 switching advantages: A diffusion-model analysis of the effects of interactional
12 context on switch costs. *Cognition*, 150, 10-19. doi:10.1016/j.cognition.2016.01.016
- 13 Hilchey, M. D., & Klein, R. M. (2011). Are there bilingual advantages on
14 nonlinguistic interference tasks? Implications for the plasticity of executive control
15 processes. *Psychonomic Bulletin & Review*, 18(4), 625-658. doi:10.3758/s13423-011-
16 0116-7
- 17 Ivanova, I., Murillo, M., Montoya, R. I., & Gollan, T. H. (2016). Does bilingual
18 language control decline in older age? *Linguistic Approaches to Bilingualism*, 6(1-2),
19 86-118. doi:10.1075/lab.15003.iva
- 20 Ivanova, I., Salmon, D. P., & Gollan, T. H. (2014). Which Language Declines More ?
21 Longitudinal versus Cross-sectional Decline of Picture Naming in Bilinguals with
22 Alzheimer's Disease. *Journal of the International Neuropsychological Society*, 20(5),
23 534-546. doi:10.1017/s1355617714000228
- 24 Jackson, G., Swainson, R., Cunnington, R., & Jackson, S. (2001). ERP correlates of
25 executive control in language-switching. *Neuroimage*, 13(6), S322-S322.

- 1 Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation
2 or not) and towards logit mixed models. *Journal of Memory and Language*, 59(4),
3 434-446. doi:10.1016/j.jml.2007.11.007
- 4 Kleinman, D., & Gollan, T. H. (2016). Speaking Two Languages for the Price of One:
5 Bypassing Language Control Mechanisms via Accessibility-Driven Switches.
6 *Psychological Science*, 27(5), 700-714. doi:10.1177/0956797616634633
- 7 Kroll, J. F., & Bialystok, E. (2013). Understanding the consequences of bilingualism
8 for language processing and cognition. *Journal of Cognitive Psychology*, 25(5), 497-
9 514. doi:10.1080/20445911.2013.799170
- 10 Lemhofer, K., Dijkstra, T., & Michel, M. C. (2004). Three languages, one ECHO:
11 Cognate effects in trilingual word recognition. *Language and Cognitive Processes*,
12 19(5), 585-611. doi:10.1080/016909604444000007
- 13 Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in
14 speech production. *Behavioral and Brain Sciences*, 22(1), 1-+.
- 15 Linck, J. A., Schwieter, J. W., & Sunderman, G. (2012). Inhibitory control predicts
16 language switching performance in trilingual speech production. *Bilingualism-*
17 *Language and Cognition*, 15(3), 651-662. doi:10.1017/s136672891100054x
- 18 Liu, H. H., Liang, L. J., Dunlap, S., Fan, N., & Chen, B. G. (2016). The effect of
19 domain-general inhibition-related training on language switching: An ERP study.
20 *Cognition*, 146, 264-276. doi:10.1016/j.cognition.2015.10.004
- 21 Macizo, P., Bajo, T., & Paolieri, D. (2012). Language switching and language
22 competition. *Second Language Research*, 28(2), 131-149.
23 doi:10.1177/0267658311434893
- 24 Magezi, D. A., Khateb, A., Mouthon, M., Spierer, L., & Annoni, J. M. (2012).
25 Cognitive control of language production in bilinguals involves a partly independent

- 1 process within the domain-general cognitive control network: Evidence from task-
- 2 switching and electrical brain activity. *Brain and Language*, 122(1), 55-63.
- 3 doi:10.1016/j.bandl.2012.04.008
- 4 Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language
- 5 Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in
- 6 bilinguals and multilinguals. *Journal of Speech Language and Hearing Research*,
- 7 50(4), 940-967. doi:10.1044/1092-4388(2007/067)
- 8 Martin, C. D., Strijkers, K., Santesteban, M., Escera, C., Hartsuiker, R. J., & Costa, A.
- 9 (2013). The impact of early bilingualism on controlling a language learned late: an
- 10 ERP study. *Frontiers in Psychology*, 4. doi:10.3389/fpsyg.2013.00815
- 11 Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of
- 12 inhibitory control in monolingual and bilingual children. *Bilingualism-Language and*
- 13 *Cognition*, 11(1), 81-93. doi:10.1017/s1366728907003227
- 14 Meuter, R. F. I., & Allport, A. (1999). Bilingual language switching in naming:
- 15 Asymmetrical costs of language selection. *Journal of Memory and Language*, 40(1),
- 16 25-40. doi:10.1006/jmla.1998.2602
- 17 Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex
- 18 function. *Annual Review of Neuroscience*, 24, 167-202.
- 19 doi:10.1146/annurev.neuro.24.1.167
- 20 Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager,
- 21 T. D. (2000). The unity and diversity of executive functions and their contributions to
- 22 complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, 41(1),
- 23 49-100. doi:10.1006/cogp.1999.0734

- 1 Orfanidou, E., & Sumner, P. (2005). Language switching and the effects of
2 orthographic specificity and response repetition. *Memory & Cognition*, 33(2), 355-
3 369. doi:10.3758/bf03195323
- 4 Paap, K. R., & Greenberg, Z. I. (2013). There is no coherent evidence for a bilingual
5 advantage in executive processing. *Cognitive Psychology*, 66(2), 232-258.
6 doi:10.1016/j.cogpsych.2012.12.002
- 7 Paap, K. R., Johnson, H. A., & Sawi, O. (2015). Bilingual advantages in executive
8 functioning either do not exist or are restricted to very specific and undetermined
9 circumstances. *Cortex*, 69, 265-278. doi:10.1016/j.cortex.2015.04.014
- 10 Philipp, A. M., Gade, M., & Koch, I. (2007). Inhibitory processes in language
11 switching: Evidence from switching language-defined response sets. *European*
12 *Journal of Cognitive Psychology*, 19(3), 395-416. doi:10.1080/09541440600758812
- 13 Poarch, G. J., & van Hell, J. G. (2012). Executive functions and inhibitory control in
14 multilingual children: Evidence from second-language learners, bilinguals, and
15 trilinguals. *Journal of Experimental Child Psychology*, 113(4), 535-551.
16 doi:10.1016/j.jecp.2012.06.013
- 17 Prior, A., & Gollan, T. H. (2011). Good Language-Switchers are Good Task-
18 Switchers: Evidence from Spanish-English and Mandarin-English Bilinguals. *Journal*
19 *of the International Neuropsychological Society*, 17(4), 682-691.
20 doi:10.1017/s1355617711000580
- 21 Prior, A., & Gollan, T. H. (2013). The elusive link between language control and
22 executive control: A case of limited transfer. *Journal of Cognitive Psychology*, 25(5),
23 622-645. doi:10.1080/20445911.2013.821993

- 1 Reynolds, M. G., Schloffel, S., & Peressotti, F. (2016). Asymmetric Switch Costs in
2 Numeral Naming and Number Word Reading: Implications for Models of Bilingual
3 Language Production. *Frontiers in Psychology*, 6. doi:10.3389/fpsyg.2015.02011
- 4 Salvatierra, J. L., & Rosselli, M. (2011). The effect of bilingualism and age on
5 inhibitory control. *International Journal of Bilingualism*, 15(1), 26-37.
6 doi:10.1177/1367006910371021
- 7 Schneider, D. W., & Anderson, J. R. (2010). Asymmetric switch costs as sequential
8 difficulty effects. *Quarterly Journal of Experimental Psychology*, 63(10), 1873-1894.
9 doi:10.1080/17470211003624010
- 10 Simon, J. R., & Rudell, A. P. (1967). Auditory S-R compatibility - Effect of an
11 irrelevant cue on information processing. *Journal of Applied Psychology*, 51(3), 300-
12 &. doi:10.1037/h0020586
- 13 Singh, N., & Mishra, R. K. (2015). The modulatory role of second language
14 proficiency on performance monitoring: evidence from a saccadic countermanding
15 task in high and low proficient bilinguals. *Frontiers in Psychology*, 5.
16 doi:10.3389/fpsyg.2014.01481
- 17 Starreveld, P. A., De Groot, A. M. B., Rossmark, B. M. M., & Van Hell, J. G. (2014).
18 Parallel language activation during word processing in bilinguals: Evidence from
19 word production in sentence context. *Bilingualism-Language and Cognition*, 17(2),
20 258-276. doi:10.1017/s1366728913000308
- 21 Struys, E., Mohades, G., Bosch, P., & van den Noort, M. (2015). Cognitive Control in
22 Bilingual Children Disentangling the Effects of Second-Language Proficiency and
23 Onset Age of Acquisition. *Swiss Journal of Psychology*, 74(2), 65-73.
24 doi:10.1024/1421-0185/a000152

- 1 Thomas, M. S. C., & Allport, A. (2000). Language switching costs in bilingual visual
2 word recognition. *Journal of Memory and Language*, 43(1), 44-66.
3 doi:10.1006/jmla.1999.2700
- 4 Tse, C. S., & Altarriba, J. (2014). The relationship between language proficiency and
5 attentional control in Cantonese-English bilingual children: evidence from Simon,
6 Simon switching, and working memory tasks. *Frontiers in Psychology*, 5.
7 doi:10.3389/fpsyg.2014.00954
- 8 Tse, C. S., & Altarriba, J. (2015). Local and Global Task Switching Costs in
9 Bilinguals Who Vary in Second Language Proficiency. *American Journal of*
10 *Psychology*, 128(1), 89-106. doi:10.5406/amerjpsyc.128.1.0089
- 11 Van Assche, E., Duyck, W., & Gollan, T. H. (2013). Whole-Language and Item-
12 Specific Control in Bilingual Language Production. *Journal of Experimental*
13 *Psychology-Learning Memory and Cognition*, 39(6), 1781-1792.
14 doi:10.1037/a0032859
- 15 van Heuven, W. J. B., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood
16 effects in bilingual word recognition. *Journal of Memory and Language*, 39(3), 458-
17 483. doi:10.1006/jmla.1998.2584
- 18 van Maanen, L., & van Rijn, H. (2010). The Locus of the Gratton Effect in Picture-
19 Word Interference. *Topics in Cognitive Science*, 2(1), 168-180. doi:10.1111/j.1756-
20 8765.2009.01069.x
- 21 Verhoef, K., Roelofs, A., & Chwilla, D. J. (2009). Role of inhibition in language
22 switching: Evidence from event-related brain potentials in overt picture naming.
23 *Cognition*, 110(1), 84-99. doi:10.1016/j.cognition.2008.10.013
- 24 Verreyt, N., Woumans, E., Vandelandotte, D., Szmalec, A., & Duyck, W. (2016). The
25 influence of language-switching experience on the bilingual executive control

- 1 advantage. *Bilingualism-Language and Cognition*, 19(1), 181-190.
- 2 doi:10.1017/s1366728914000352
- 3 von Bastian, C. C., Souza, A. S., & Gade, M. (2016). No Evidence for Bilingual
- 4 Cognitive Advantages: A Test of Four Hypotheses. *Journal of Experimental*
- 5 *Psychology-General*, 145(2), 246-258. doi:10.1037/xge0000120
- 6 von Studnitz, R. E., & Green, D. W. (2002). The cost of switching language in a
- 7 semantic categorization task. *Bilingualism-Language and Cognition*, 5(3), 241-251.
- 8 doi:10.1017/s1366728902003036
- 9 Weissberger, G. H., Wierenga, C. E., Bondi, M. W., & Gollan, T. H. (2012). Partially
- 10 Overlapping Mechanisms of Language and Task Control in Young and Older
- 11 Bilinguals. *Psychology and Aging*, 27(4), 959-974. doi:10.1037/a0028281
- 12 Woumans, E., Ceuleers, E., Van der Linden, L., Szmalec, A., & Duyck, W. (2015).
- 13 Verbal and Nonverbal Cognitive Control in Bilinguals and Interpreters. *Journal of*
- 14 *Experimental Psychology-Learning Memory and Cognition*, 41(5), 1579-1586.
- 15 doi:10.1037/xlm0000107
- 16 Yang, H. J., Hartanto, A., & Yang, S. J. (2016). The Complex Nature of Bilinguals'
- 17 Language Usage Modulates Task-Switching Outcomes. *Frontiers in Psychology*, 7.
- 18 doi:10.3389/fpsyg.2016.00560
- 19 Yow, W. Q., & Li, X. Q. (2015). Balanced bilingualism and early age of second
- 20 language acquisition as the underlying mechanisms of a bilingual executive control
- 21 advantage: why variations in bilingual experiences matter. *Frontiers in Psychology*, 6.
- 22 doi:10.3389/fpsyg.2015.00164
- 23 Zhang, H. Y., Kang, C. Y., Wu, Y. J., Ma, F. Y., & Guo, T. M. (2015). Improving
- 24 proactive control with training on language switching in bilinguals. *Neuroreport*,
- 25 26(6), 354-359. doi:10.1097/wnr.0000000000000353

- 1 Zhou, B. N., & Krott, A. (2016). Data trimming procedure can eliminate bilingual
- 2 cognitive advantage. *Psychonomic Bulletin & Review*, 23(4), 1221-1230.
- 3 doi:10.3758/s13423-015-0981-6

4